THE TRANSMISSION OF COMPUTER DATA

Computer users are sending an increasing volume of digital data over the nation's electrical communication network. To transmit such data efficiently at high speed, the network is being modified

by John R. Pierce

Electrical communication is an adaptation of science and technology to the service of man. Computers too are servants of men. Computers can respond to and interact with man directly and immediately, as an automatic telephone switching system or an airline reservation system does. Or computers can do assigned chores and report back to man intermittently, as they do in inventory control or the making up of payrolls. In either case computers and the data they manufacture must somehow enter into the pattern of man's telecommunication.

Modern electrical communication had its origin in two apparently distinct inventions of the 19th century. One of these was the telegraph, which transmitted information by means of on-off signals that produced audible clicks. The receiving operator interpreted these clicks as letters and words of a message; he transcribed the message on a piece of paper or, in some instances, spoke it to an expectant recipient. The other early invention was the telephone, which transmitted, over a limited distance and faintly, the sound of the human voice.

I think we should add to these two inventions another two that are crucial to human uses of electrical communication. These are automatic telephone switching, which first brought man into large-scale contact with complicated logical machines, and the teletypewriter. These inventions enabled men who had no special training (such as the training of telegraph operators) to communicate electrically by dialing or by typing letters and numbers.

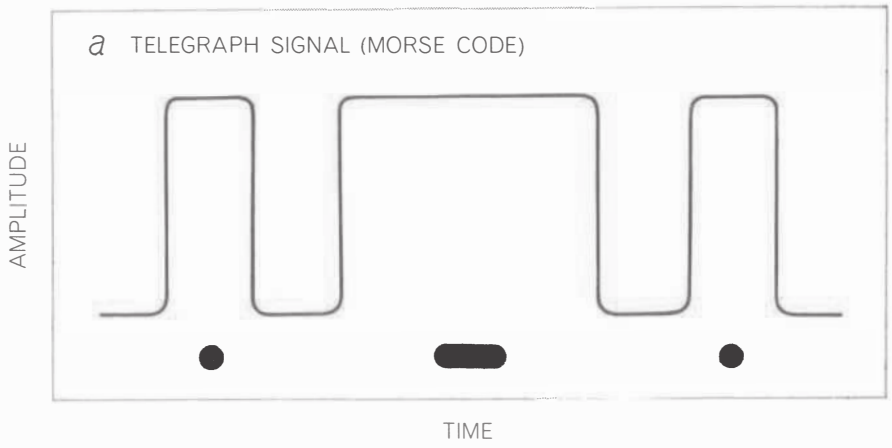
As we look back on the early telegraph and the early telephone, we see that they were as specialized as they were simply because of the limitations of the electrical art of their time. Even then, however, they were not entirely separate. Alexander Graham Bell discovered the telephone while working toward a harmonic telegraph, in which different signals would be simultaneously conveyed over the same pair of wires by electrical tones of different frequency. Still, for a long time there seemed to be some sort of intellectual or electrical distinction made between the kinds of signals employed for telegraphy and telephony.

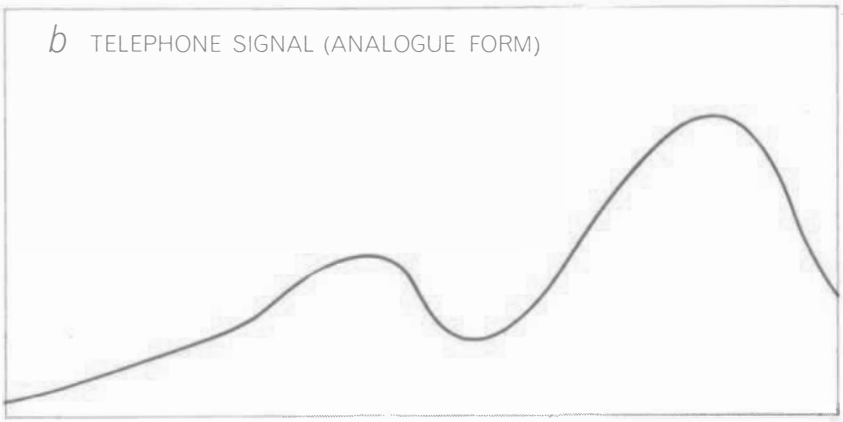
This distinction gradually became less clear as telegraph signals were multiplexed—transmitted many at a time—over telephone lines in much the way Bell had envisioned in his work on the harmonic telegraph. Recently it has been shown that telephone signals can be transmitted by on-off impulses, using the method known as pulse-code modulation (PCM). In this method the varying amplitude of the telephone signal is sampled at frequent intervals and coded in numerical values, which are then converted into binary digits for transmission. At the receiving end of the line the operation is reversed [*see illustration on next page*].

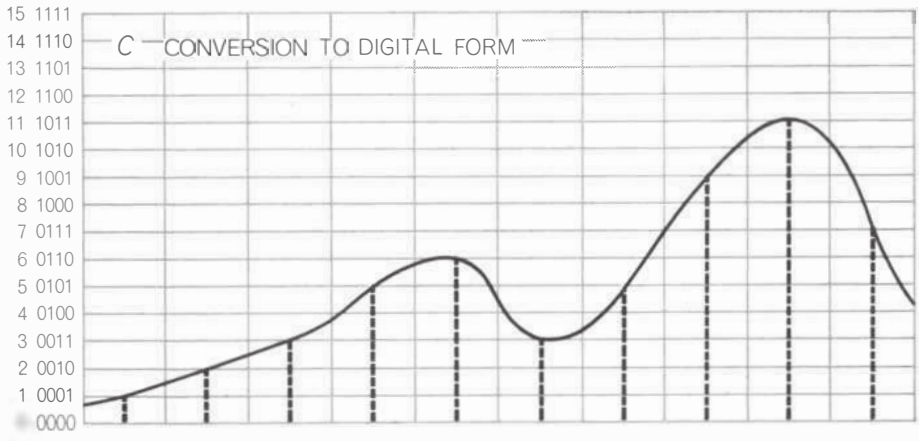
Thus we have begun to see in electrical communication something of the universality of man's behavior and man's nervous system. We all use a mixture of reading and writing, listening and speaking and even gesturing in everyday life. In the human nervous system we find no distinction among the signals associated with different human senses and activities. The nerve impulses that travel from our fingers to our brain in the operation of the sense of touch, the nerve impulses that travel from the eyes to the brain in vision and the nerve impulses from the ear to the brain in hearing are all the same spikelike electrical signals. There is a uniform medium through which all our senses serve us. The same spikelike pulses control the muscles we use in writing and those we use in speaking. The human body employs a common communication system for both sensory and motor activities. The differences among such activities lie in the differences among the various sensors and effectors and in the functioning of the central nervous system.

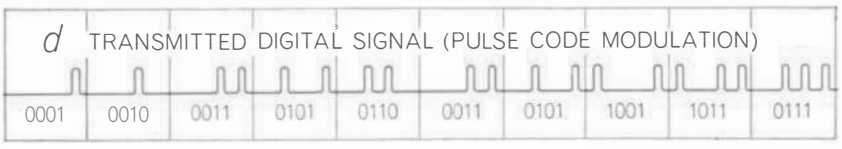
In 1948, quite late in the evolution of communication technology, a logical framework was developed that is capable of describing, unifying, and quantifying the process of communication and control. Claude E. Shannon, then a young mathematician working for the Bell Telephone Laboratories, inquired: What are we really trying to do in the process of communication? This process, he said, begins with a source of information, which generates information at some particular rate. Information from the source is encoded and then transmitted over a communication channel. At the far end the message is decoded and a replica of the information at the source arrives at a destination.

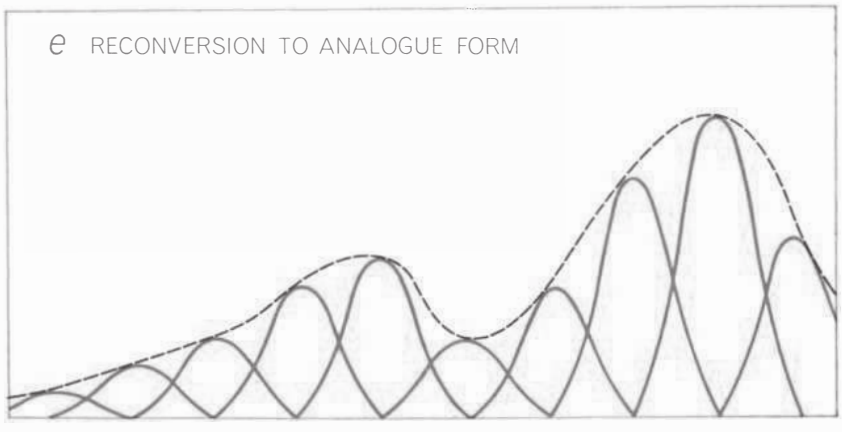
MICROWAVE ANTENNAS (*opposite page*) **are clustered on the roof of the headquarters building of the long-lines department of the American Telephone and Telegraph Company in New York. The shedlike structures are microwave horns of two types: "delayed lens" and "cornucopia." Each radiates a microwave beam that can carry 600 one-way telephone channels. There are 10 such horns on the roof, not all of them visible. The roof also carries two dish reflectors used for temporary service and a variety of mobile-radio antennas.**











In order to talk sense about the process Shannon had to have a measure of the information rate of the source and a measure of the information capacity of the communication channel. He defined a universal measure and a universal unit of information: the bit (binary digit). A bit is the choice between plus or minus; it is the amount of information needed to remove the uncertainty between yes or no. It is a distinct choice, and hence it reminds us of the on-off character of the telegraph signal, but it is a universal choice. It applies equally well to the information rates and channel capacities of telegraph signals, voice signals, picture signals, and the signals that circulate through modern electronic digital computers and telephone switching systems. Through Shannon's work our conception of communication has come to fit the actual nature of electrical communication systems: circuits that can be used interchangeably for telegraph, voice and picture signals.

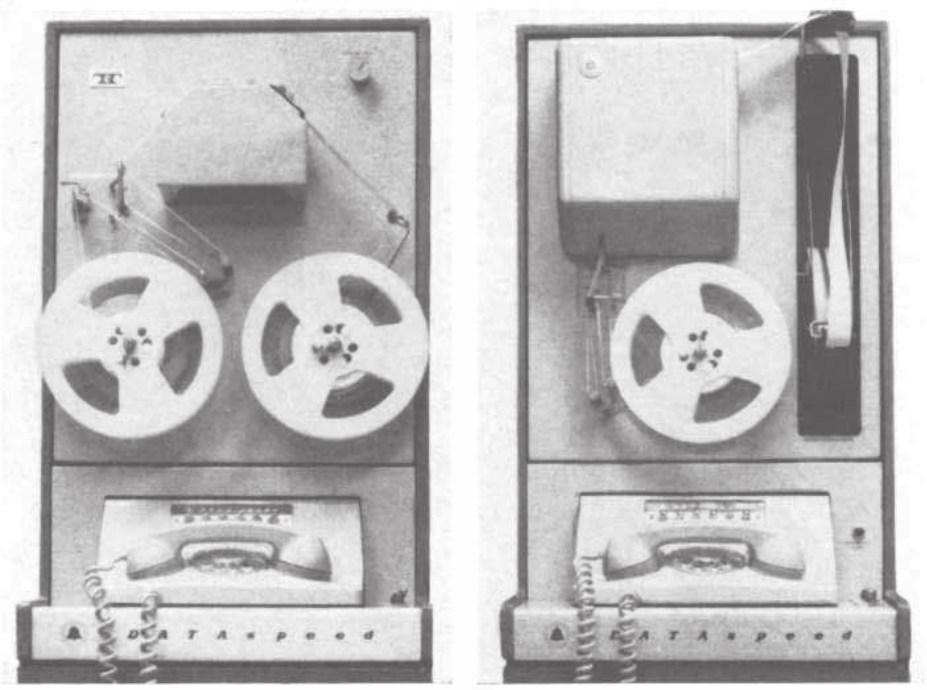
Shannon's equations demonstrated for the first time just how wasteful most communication channels are. He showed, for example, that a letter of English text contains only about one bit of information, if due allowance is made for letter frequencies in English words and the predictable constraints that exist in all written languages. In other words, with an efficient coding scheme one should be able to transmit ordinary English text with an expenditure of one bit per letter. Thus the information contained in a typical 300-word page of typewritten text is only some 1,800 bits. To transmit 300 words with ordinary data-transmission coding techniques, however, requires the expendi-

SIGNAL-CODING takes two basic forms: digital and analogue. A digital signal carries information in the form of pulses. Morse code (*a*) is an early example of a digital code in which the pulses vary in duration but not in amplitude. An analogue signal, such as a telephone signal (*b*), varies continuously in amplitude. An analogue signal can be converted to digital form by sampling its amplitude at regular intervals and assigning a numerical value to each sample (*c*). The numerical values of the samples can be converted to binary digits and transmitted as a sequence of 0's and 1's (*d*). This signaling method is called pulse-code modulation. At the receiving end of the line the binary numbers can be converted to smoothed pulses whose amplitude is proportional to the size of the number (*e*). The sum of these pulses regenerates the original analogue signal.

ture of about 12,600 bits (a seven-bit code group for each letter). To transmit a page of text by facsimile requires about a million bits. In this case, of course, the entire page is transmitted as a picture, which is mostly white space. If the page were read aloud over a pulse-code-modulation telephone channel, one would need more than 11 million bits to transmit it. Finally, if the same page were transmitted by television for the time needed to read it aloud (say three minutes), more than 10 billion bits would be required. An obvious way to reduce the number of bits transmitted in this case would be to send the picture once, which would take only a thirtieth of a second, and then send a few bits of information containing the message: "Hold picture on screen for three minutes." Something analogous does happen, in fact, when a few lines of input to a computer result in many pages of print-out. In Shannon's sense there is no more information in the print-out than in the input that gave rise to it. Accordingly any message that can be generated at the terminal of a communication channel contains no information beyond the local input needed to produce it and therefore need not be transmitted.

This brief excursion into information theory is relevant because the users of computers are increasingly concerned about whether to install a computer at the site where computer problems exist or to transmit the problems to a computer at a remote site. By adopting the latter course one may be able to justify the installation of a large computer that can handle many inputs by the technique of time-sharing [see "Time-sharing on Computers," by R. M. Fano and F. J. Corbató, page 128]. Information theory makes it clear, however, that the "information" transmitted from the computer back to one of the time-sharing stations is not truly information. One can therefore afford to transmit it only as long as communication channels are cheaper than the computing machinery needed to generate it. The debate about when it is cheaper to transmit and when it is cheaper to compute has been agitating the computer industry for several years and will doubtless continue to do so as economic advantages swing one way and then another.

Still, it takes little imagination to foresee that in a world filled with computers as well as people the communication mix will be vastly different from what it is today. The trend is already foreshadowed in the use being made of the long-lines circuits of the Bell System [*see top illustration on next page*]. For the past 10 years "special service" circuits have been growing much faster than "message" circuits. The latter are used for ordinary switched telephone calls. The former are circuits, usually of the same nature, that are not used as part of the switched telephone plant but are used rather for the transmission of data, television, radio programs or the voice part of the television signal, facsimile, nonswitched private-line telephony or some other special service. The growth of special-service circuits reflects several areas of use: data transmission, closed-circuit television for educational and other purposes, and networks of circuits rented to large companies, sometimes for a highly mixed usage.



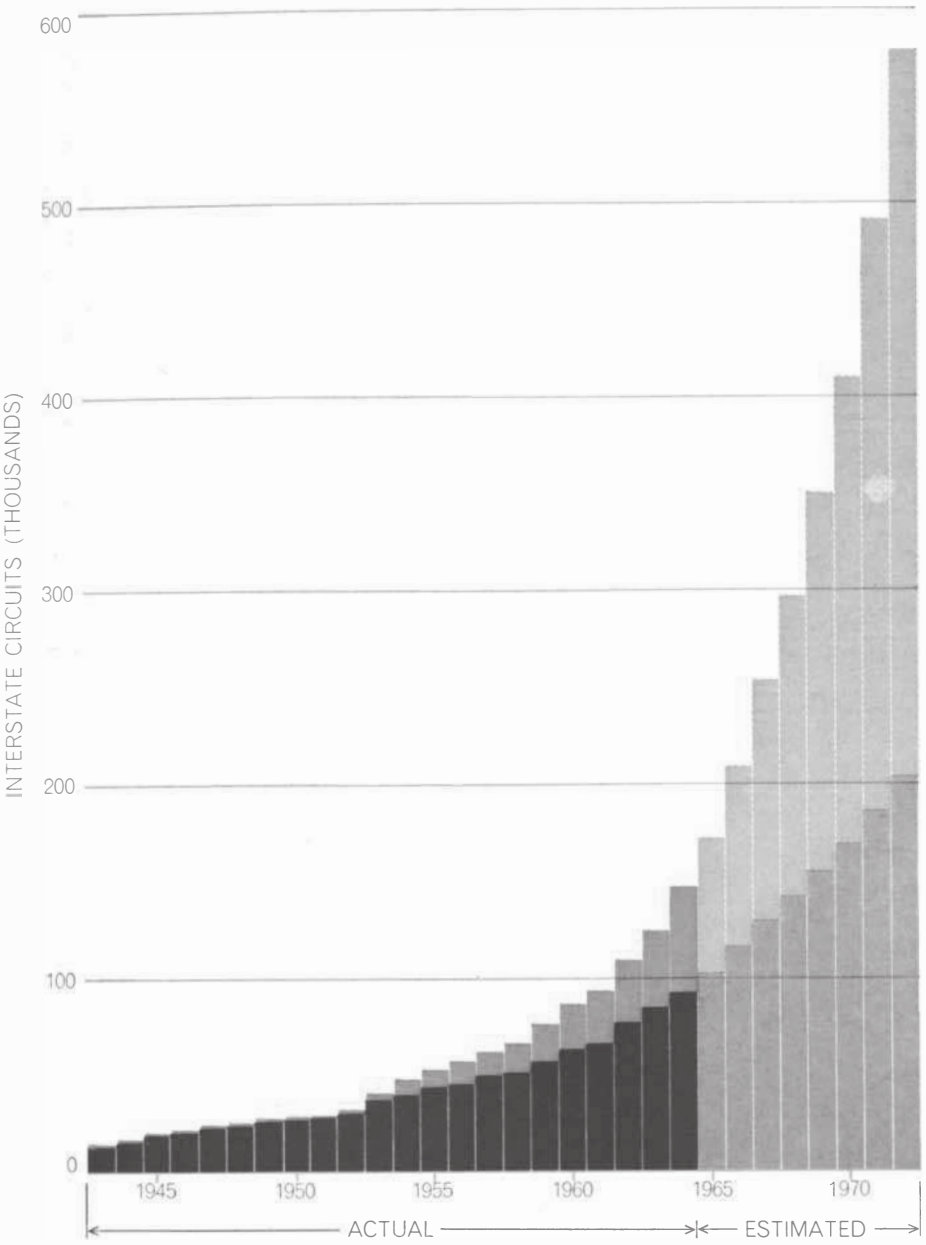
BELL SYSTEM'S "DATASPEED" service provides a convenient way to send digital data over a standard telephone channel. The transmission rate of Dataspeed is 1,050 words (about 70,000 bits) per minute. A Dataspeed sender is at the left, a receiver is at the right.

It is important to realize that, although the distinction between messages and special services is an important one, it is not a distinction between data and voice. Some of the most promising prospects of data transmission involve the telephone-message network. In Wilmington, Del., a person with an account at the Bank of Delaware can pay for a purchase at the nearby Stroms department stores even if he has left his wallet home and has no credit account at Stroms. After a purchase the salesclerk simply "dials" the number of the bank on a push-button ("Touch-Tone") telephone, enters a code that identifies the customer and then enters the amount of the purchase. Other banks that are pioneering in similar services include the Mercantile Trust Company N.A. of St. Louis, the Wells Fargo Bank of San Francisco and the Manufacturers Bank of Detroit.

The interaction of men and computers is not limited to "data" signals; it can involve voice or visual signals. Moreover, unlike the pulses produced by a telephone dial, the signals produced by push-button signaling resemble musical notes; they can be transmitted over any voice circuit and hence can be used to interrogate remote computers. How can the computer answer? In a system used by the Bankers Trust Company the computer responds over the line by a recorded voice.

We should also realize that in an up-to-date computer center much of the output may be graphs, diagrams and drawings rather than tabular print-out. The most efficient means for transmitting graphical material is to transmit the coded directions that would ordinarily be fed to the output device that makes the drawing. This means that a graphical output device with a considerable logical capability—a small computer in itself—must be used at the receiving end. In some cases this may prove impractical, and less efficient television or facsimile transmission may then be employed.

Similarly, computers can make use of



LONG-LINES CIRCUITS of the Bell System are increasing steeply. The black portion of each bar represents circuits used for conventional telephone messages. The portion in color represents equivalent voice circuits used for special services, such as facsimile, television and data of various kinds. Such circuits are expected to exceed message circuits next year.

TRANSMISSION SYSTEM	BITS PER SECOND	ONE-WAY TELEPHONE CHANNELS
PAIR OF WIRES (ONE WAY)	6×10^6	96
SINGLE COAXIAL CHANNEL (ONE WAY)	30×10^7	~5,000
COAXIAL CABLE (10 CHANNELS EACH WAY)	60×10^8	~100,000
WAVE GUIDE (TWO-WAY SYSTEM)	120×10^8	~200,000

CHANNEL CAPACITIES of four transmission systems capable of carrying either voice signals or data are shown here. In a coaxial cable only nine channels are ordinarily in use each way; the 10th is held as a spare. Wave guides are pipes, usually about two inches in diameter, that can carry broad-band microwave signals with small transmission losses.

graphical inputs. Again the efficient mode of transmission is to have a small computer to encode the input at the transmitting end, but again facsimile or even television might find a place putting graphical material into computers.

In the more distant future it may be possible to control computers, including telephone switching systems, by the human voice. Progress is being made in the automatic identification of speakers by voice, as a substitute for a handwritten signature, and this could play an important part in banking and other credit transactions.

The prospect before us, then, is a large growth in the use of all kinds of special signals in communicating with computers as well as with human beings. The flexible and universal nature of electrical communication will continue to make it possible for communication to grow freely and flexibly in meeting needs that have been and will continue to be less than completely predictable.

If we were to start afresh in building a universally adaptable communication network, there are persuasive arguments that it should transmit digital signals exclusively. Voice and other signals can now be converted economically to and from digital form at telephone offices. Digital signals could then be used in terminal equipment and throughout the switching apparatus. Such primitive signals are unspecialized, and can be used easily for any form of communication. About 64,000 binary pulses a second will provide a telephone circuit and about 64 million suffice for commercial television.

In the days of the vacuum tube such a digital network would have been uneconomical, but the transistor has made digital transmission practical, and the impending microelectronic revolution will steadily lower the cost of both digital transmission and digital processing, including digital switching.

Using today's technology, we could construct apparatus that would economically:

Transmit pulses over a single pair of wires at rates up to six million bits per second.

Transmit pulses through a coaxial channel at rates up to 300 million bits per second (a total capacity of three billion bits per second each way through a 20-unit coaxial cable).

Transmit six billion bits per second each way through a two-inch wave guide by means of radio waves whose

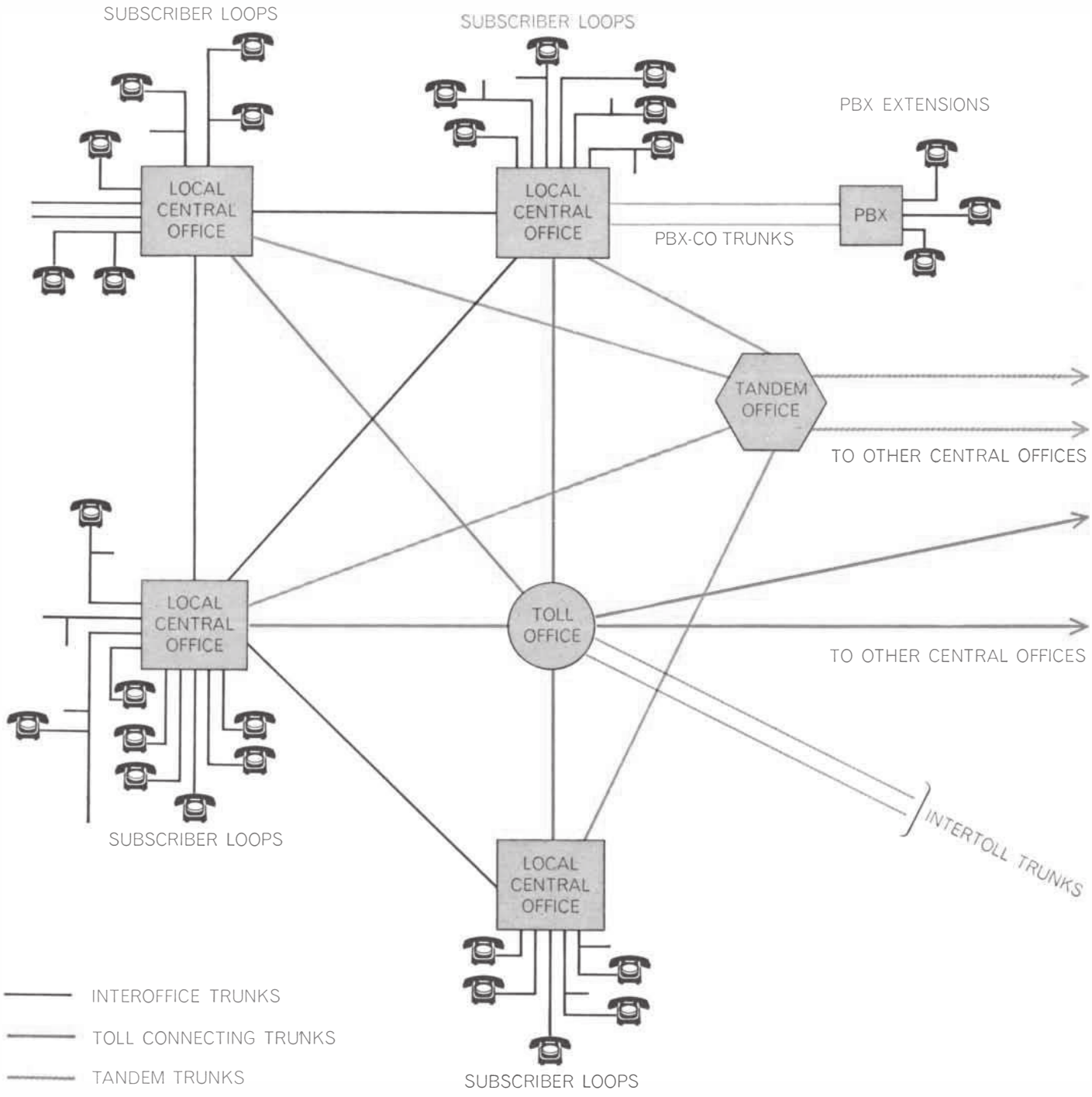
wavelength is measured in millimeters.

Transmit a total of six billion bits per second between various pairs of telephone offices by means of a single hovering artificial satellite.

For better or worse, it would be idle to assume that there will be all-digital transmission in any near future. For an all-digital system to be useful it would have to extend to anyone who wanted communication service. For the cost of such a system to be bearable the traffic would have to be great. One cannot start entirely afresh and build a universal digital-transmission system, first because the undertaking would be impractically large and second because the initial traffic such a system would handle is already accommodated by existing facilities.

What, then, do we have, and where are we going? There are in the country a number of private transmission systems (predominantly microwave-radio systems) owned by large users. The bulk of traffic, however, goes over common-carrier telephone and telegraph company lines. Of the traffic borne by common carriers the bulk of the facilities are those of the telephone companies, both Bell System and independent. These facilities have a capital value of some $30 billion. They consist of a great many kinds of equipment, old and new, which through a process of orderly development and evolutionary accommodation can work together in handling a variety of traffic.

A small part of the Bell System transmission equipment is already digital. The "T1" transmission system sends 1.5 million binary pulses per second for distances between five and 50 miles. A twisted pair of wires in a cable is used for each direction, and regenerative repeaters every mile amplify and reshape the train of pulses. The T1 system is widely installed. In Massachusetts, for



TELEPHONE NETWORK is designed in hierarchical fashion. When a call is placed to someone in the immediate neighborhood, the connection is usually made in the local central office. Calls to more distant points may involve "toll offices" or "tandem offices."

example, a network of T1 systems will soon cover the entire state. The system is used predominantly for telephony, but it is also used for data transmission, including facsimile. It is well suited to the visual telephone ("Picturephone"). Other digital-transmission systems are under development, including a T2 system with four times the bit capacity of the T1 and a T4 coaxial-cable system with nearly 200 times the capacity of the T1.

The rest of the common-carrier plant—transmission and switching—was designed primarily for sending analogue signals such as voice. The amplitude of an analogue signal varies over a period of time in a smooth way, and in certain respects this variation must be reproduced with high precision.

To achieve the universality necessary for effective communication, common-carrier facilities are interconnected in a hierarchical manner. Let me illustrate by describing the switched-message telephone plant.

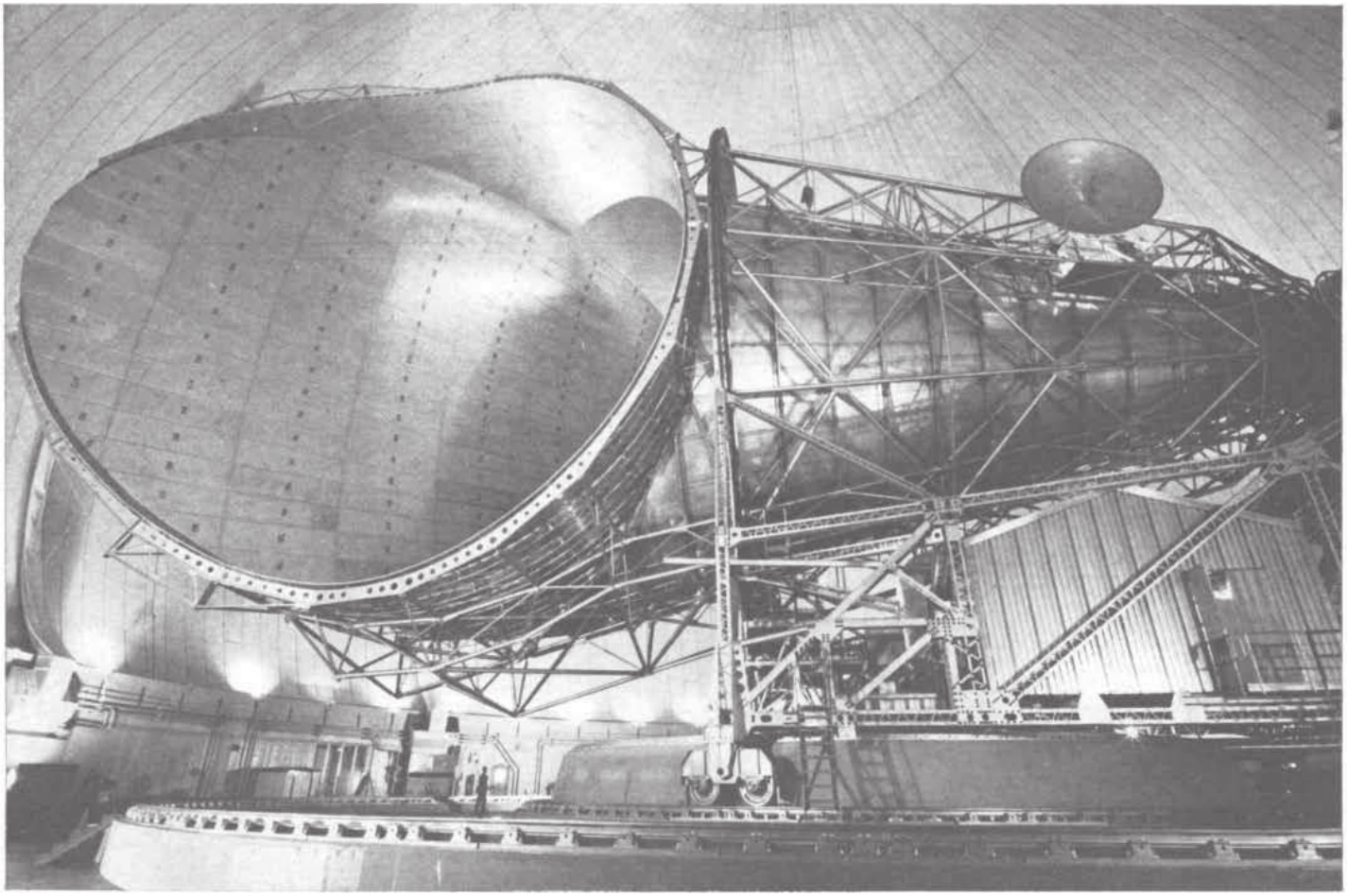
Although most of the world's 182 million telephones are interconnected, we shall consider only the 95 million telephones in North America. Among the 95 million telephones there are more than 4×10^{15} possible interconnections. It is ridiculous to imagine this number of individual circuits interconnecting the telephones of the country. Clearly some more sensible means of interconnection must be employed. The illustration on the preceding page gives a clue to what it is.

The "subscriber's loop" from your house goes to a local central office, along with between a few hundred and as many as 50,000 other subscriber's loops. When you talk with another subscriber who is connected to the same central offices in one area, it is uneco- his right at that office. In a large metropolitan area there will be many central offices. When there is heavy traffic between nearby offices, those offices will be connected by interoffice trunks.

When there are a large number of central offices in one area, it is uneconomical to provide an adequate number of trunks between all central offices, just as it is uneconomical to interconnect all telephones pair by pair. Instead a tandem office is set up, connected to each of the local central offices it serves by tandem trunks. Finally, one may wish to talk with someone else in a distant city. In that case the call will go from the local central office to a toll office and thence over an intertoll trunk to some other toll office.

There is also a hierarchical organization of the facilities used to transmit signals between various parts of the system. The subscriber's loop is a twisted pair of copper wires in a cable, without means of amplification. Amplifiers are sometimes needed for a long loop.) The subscriber's loop is a two-wire circuit, that is, voice signals are transmitted simultaneously in both directions over the same pair of wires. Because the means of suppressing interference between the signals going in opposite directions is not quite perfect, some of the signal going toward a subscriber is reflected back toward the sender. Although this defect is unobjectionable in voice communication, it makes it impractical to use simple two-wire circuits for the simultaneous two-way transmission of data.

The next level in the hierarchy employs four-wire systems, which provide independent circuits for the two direc-

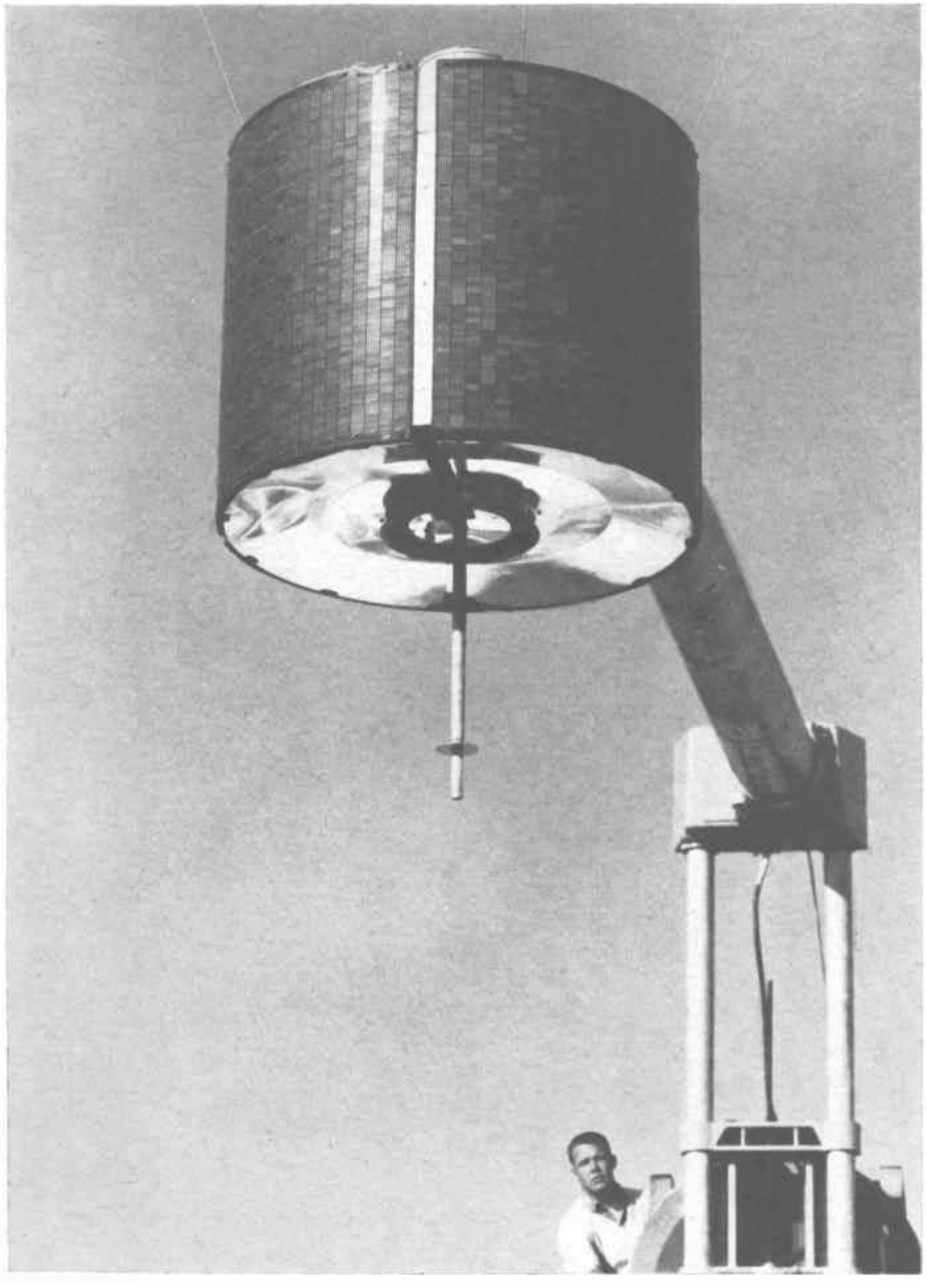


SENSITIVE MICROWAVE ANTENNA at Andover, Me., is operated for the Communication Satellite Corporation by the Bell System. Originally designed to track Bell's Telstar, the antenna is now kept fixed on Early Bird, the synchronous satellite built for Comsat by the Hughes Aircraft Company. The author was among the first to urge the development of communication satellites.

tions of transmission. In these systems, which interconnect toll offices, the band of frequencies constituting a telephone channel is shifted up in frequency so that many channels can be "stacked" one above another in frequency and transmitted through amplifiers and over cables without interference. This technique is known as frequency-division multiplex.

For long-haul transmission hundreds of channels are transmitted over one coaxial cable, or one microwave link, or one submarine cable, or one communication satellite. At present all long-haul systems use frequency-division multiplex. They all employ a standard pattern in shifting the frequencies of voice channels and combining them. A "channel bank" is used to combine 12 voice channels into a group by shifting their frequencies. A "group bank" is used to combine five groups into a supergroup (60 channels) by another frequency shift. A "supergroup bank" is used to combine 10 supergroups into a master group (600 channels) by means of still another frequency shift. By a further frequency shift several master groups can be sent over one long-haul system.

Because of this hierarchical procedure various channels with a bandwidth broader than a telephone channel are readily available in the telephone network. These are the group, with a bandwidth of about 48,000 cycles; the supergroup, with a bandwidth of about 240,000 cycles, and the master group, with a bandwidth of about 2.4 million cycles. Such broad-band channels are commonly employed in data transmission and facsimile transmission. If the demand arises, data can be sent over the channels of still wider bandwidth (about 4.1 million cycles) developed to carry television signals.



EARLY BIRD, built by Hughes Aircraft, was placed in a synchronous orbit some 22,300 miles above the equator in April, 1965. At that altitude its period of rotation is exactly 24 hours, with the result that it appears to stay fixed above a point in the South Atlantic. From that position Early Bird can relay radio and television signals uninterruptedly between the U.S. and Europe. It seems likely that far more capacious synchronous satellites will eventually be needed to supply communication channels between cities within the U.S.

For some years in the future common-carrier circuits that were designed primarily for voice signals will be used to transmit a wide variety of new kinds of signal, including digital, facsimile and Picturephone signals. Special end links, such as those provided by the T1 digital system, will come into play, and long-haul digital transmission will be introduced gradually in such a way that it can operate interchangeably with present facilities. Nonetheless, new kinds of communication cannot wait for the construction of an entirely new common-carrier plant.

Present circuits derived from frequency-division multiplex systems are rather sophisticated from the point of view of information theory. They are tailored to the statistical analysis of voice signals and conversations. If they are required to carry a large number of data signals that "talk" all the time with the same "loudness," they can be overloaded.

Furthermore, the ear does not mind if some frequency components of a signal arrive a little earlier or a little later than others, but this is intolerable in the transmission of pulses. To transmit pulses efficiently over a circuit designed for voice a device called an equalizer must be used, and this device must be tailored to the particular circuit.

Finally, our sense of hearing is insensitive to moderate, gradual changes in level. In transmitting digital signals efficiently over a circuit, however, it may be necessary to distinguish among 16 or more precise amplitudes. The control of level is therefore another problem.

In the economics of data transmission the cost of the "data set," which adapts a circuit for data transmission, may be paramount. On the other hand, a high rate of transmission in bits per second may be the most important factor. Therefore cheap data terminals that will squeeze more bits per second through a circuit are also needed.

Let us consider sending data over a

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Channel 1 Characteristics (Audio Channel)

1. Frequency Response: 20-2000 cps 3 db.
2. Signal Sensitivity: ±0.5V for full scale recording to ±5V by adjustment of built in attenuator.
3. Input Impedance: Hi-Z input 1 megohm. Lo-Z input 600 ohms.
4. Output Level: ±2.5V full scale recording.
5. Output Impedance: Less than 100 ohms.

Channel 2 Characteristics (FM Channel)

1. Frequency Response: 0 to 200 cycles.
2. Signal Sensitivity: as in "2" of Channel 1.
3. Input Impedance: 1 megohm.
4. Output Level: ±2.5V full scale recording.
5. Output Impedance: less than 100 ohms.
6. Multiplexed Flutter Compensation for high signal-to-noise ratio.
7. Signal-to-Noise Ratio: 44db 0-200 cycles, 57db 0-45 cycles.

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telephone circuit. A simple data set will transmit up to 300 bits per second over any circuit. A slightly better set will transmit up to 600 bits per second. A set that does not use a binary signal but transmits four different kinds (frequencies) of signals will transmit up to 2,400 bits per second. All these data sets are available commercially [*see illustration on page 147*].

Beyond this level of performance experiments have been done showing that it is possible to transmit over a telephone channel up to 5,400 bits per second, and perhaps more than 9,000 bits per second. Such transmission calls for error-correcting codes and automatic equalizers, which adjust themselves to the characteristics of the particular circuit.

These rates are not high enough for many applications. Accordingly data sets are available that will transmit up to 19,200 bits per second over six voice channels, up to 50,000 bits per second over 12 voice channels (a group) and up to 230,400 bits per second over 60 voice channels (a supergroup). Finally, it is possible to use a standard television channel for transmission at rates up to several million bits per second. In addition to development work on a long-haul coaxial-cable system for more economical data transmission over long distances, experimental work is under way on the transmission of more bits per second over existing long-haul coaxial and microwave systems.

Providing broad-band transmission of various kinds is complicated by the fact that long-haul transmission systems in general link only toll offices. Therefore, although it is easy to extend voice circuits from any central office to a subscriber over existing wires, special arrangements must be made in order to supply broad-band data or other services to a subscriber. Fortunately the T1 digital-transmission system, which works over a pair of wires in a cable, provides an economical means for doing so. An alternative is simple short-haul microwave systems.

Transmission is, of course, only part of the problem. Various services are now available that supply circuits for a user's exclusive use. Telephone message service provides connections of any duration for the transmission of voice, data or other kinds of information. Some users, however, want channels of greater bandwidth than voice channels on a switched, or nonprivate, basis.

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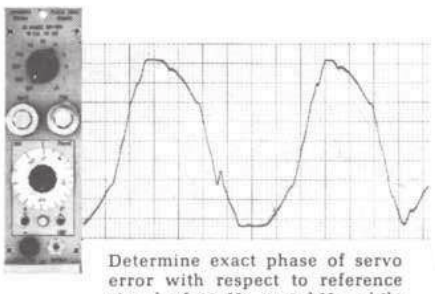
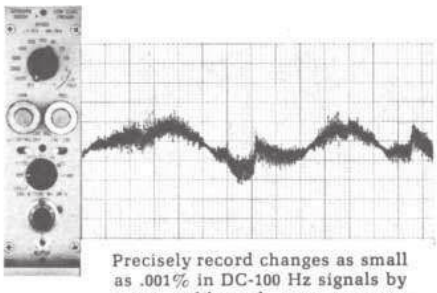
Bring on your complex, small, noisy, difficult signals.

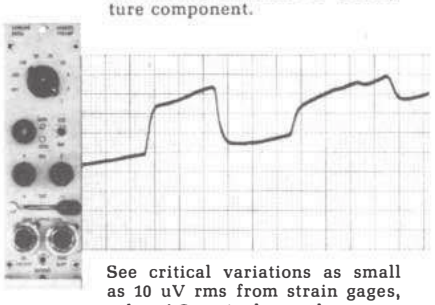
We'll give you traces that show them for what they really are.



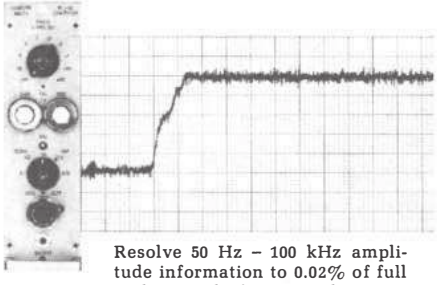
Determine exact phase of servo error with respect to reference signal of 60 Hz to 5 kHz while maximizing rejection of quadrature component.



Precisely record changes as small as .001% in DC-100 Hz signals by using calibrated zero suppression.



See critical variations as small as 10 uV rms from strain gages, other AC-excited transducers.



Resolve 50 Hz – 100 kHz amplitude information to 0.02% of full scale signals from 1 volt to 500 volts.

When you need the greatest possible degree of signal-conditioning precision and operational control, Sanborn 7700 Series oscillographs with solid-state "8800" plug-ins will give you chart recordings of *maximum resolution and intelligibility*.

Seven highly versatile signal conditioners offer unique performance capabilities: three DC types with a 1 uV–250 V dynamic range, floating differential input and calibrated zero suppression . . . an AC-DC Converter with calibrated zero suppression and scale expansion permitting resolution better than 0.1%, 10 ms response and isolated, 1 meg. input . . . a phase-sensitive demodulator with calibrated reference phase shift, 90° calibrated dial with four quadrant selections, and a frequency range of 60 Hz to 5 kHz . . . a carrier preamplifier with 2400 Hz internal transducer excitation supply, calibrated zero suppression, cal. factor control and conversion gain of 10,000 . . . and a general-purpose DC preamp particularly useful for 100 mm wide chart recording.

Use any of these "8800" plug-ins in the 7700 thermal writing oscillograph matched to your packaging and channel requirements — 4-, 6- and 8-channel 7704A, 7706A and 7708A console types . . . 2-channel 7702A system in rack-mount or mobile cart versions . . . single-channel 7701A wide chart (100 mm) portable system. Every one of these thermal writers will give you permanent, rectangular-coordinate recordings whose resolution and accuracy make all your measurements more useful.

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system provides medium-band switched service, but only between locations near certain key cities. Telephone companies have provided switched data service for group bandwidths on a "private line," or "private network," basis and plan to introduce a general wide-band switched data network.

New uses of communication provide new operational problems. Switched data circuits may be in operation for hours at a time; this is much longer than a telephone call. Some users would occasionally like to have a narrow-band or a broad-band circuit for a minute or less at a time. This means that the switching time required for setting up the connection might be comparable to the time the connection was in use. No doubt electronic switching, employing transistors, will ultimately lead to much shorter switching times than is now possible with electromechanical switching systems employing relays, but the electronic switching capacity now installed is small, and electromechanical switching will predominate for many years.

One obstacle to rapid progress in new uses of communication is the weight of tradition. New uses, even of existing equipment, call for new "packaging." The user wants to buy a service he needs right now, not a service someone else needed years ago. It is not easy to devise standard packages that are acceptable and economical. Moreover, no new service can be offered without the consent of regulatory bodies, and without their first assuring themselves that the new service is "compensatory" according to traditional standards.

The evolution of electronic computers, together with many other advances, is extending communication and the need for communication facilities of a great variety. Even in communication with computers, however, one cannot be sure how much of the communication will be data, how much voice and how much graphical material. The immediate problem is to send all kinds of signals, including data signals, over existing circuits. Only in that way can we have from the start the universality of communication to which telephony has accustomed us.

The fact remains that digital transmission is increasingly attractive for sending all kinds of signals. Indeed, we are probably in a period of evolution that will lead us more and more toward completely digitalized communication service—from the subscriber, through the switching operations and to the farthest reaches of the earth.